NETWORK SIMULATION SYSTEM AND METHOD

RELATED APPLICATIONS

This application claims the benefit of U.S.

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Field of the Invention

The present invention relates to a simulation

network and, more particularly, to a composite broadcast

system for simulating processes such as manufacturing

10   processes, war games, or entertainment games.

Background of the Invention

A necessity in a conventional simulation system is

the ability to link, or network, various simulation

environments together. Each environment is typically a

15   simulation laboratory and is confined to its own

subnetwork. Each of these subnetworks must be connected,

or mirrored, in order to form one network. The

subnetworks may be any combination of single ring, double ring, bus, star, or other suitable subnetworks.

A conventional simulation system utilizes computers that are in close proximity to each other and/or have dedicated hardwire connections to each other. Another conventional simulation system utilizes a combination of plural simulation devices having dedicated hardwire connections located throughout proximal locations. Eliminating these constraints by using the Internet or an undedicated intranet for the necessary connections, without losing the complete confidentiality and reliability required for many simulations, would allow human operators to take part in the simulations while being located at different remote locations throughout the United States and even other parts of the world.

Such simulations could then reliably and efficiently be conducted within the framework of client server database systems, instant notification/messaging applications, rudimentary data transfer, etc. Thus a system in accordance with the present invention may utilize existing communication networks for new and ever changing applications.

Summary of the Invention

In accordance with the present invention, a method allows communication within a network. The method

includes the steps of: transmitting a data packet as a broadcast signal from a first application node of a first subnetwork to a first gateway node of the first subnetwork; transmitting the data packet as a point-to-point signal from the first gateway node to a second gateway node of a second subnetwork; and transmitting the data packet as a broadcast signal from the second gateway node of the second subnetwork to at least one application node of the second subnetwork.

In accordance with another feature of the present invention, a system simulates a war game. The system includes a first device, a second device, and a third device. The first device transmits a data packet as a broadcast signal from a first application node of a first subnetwork to a first gateway node of the first subnetwork. The second device transmits the data packet as a point-to-point signal from the first gateway node to a second gateway node of a second subnetwork. The third device transmits the data packet as a broadcast signal from the second gateway node of the second subnetwork to at least one application node of the second subnetwork.

In accordance with still another feature of the present invention, an apparatus simulates a war game. The apparatus includes a first means, a second means, and a third means. The first means transmits a data packet

as a broadcast signal from a first application node of a
first subnetwork to a first gateway node of the first
subnetwork. The second means transmits the data packet
as a point-to-point signal from the first gateway node to

5   a second gateway node of a second subnetwork. The third
means transmits the data packet as a broadcast signal
from the second gateway node of the second subnetwork to
at least one application node of the second subnetwork.

In accordance with yet another feature of the

10   present invention, a computer program product
communicates within a network. The product includes a
first subnetwork and a second subnetwork. The first
subnetwork has a first application node and a first
gateway node. The second subnetwork has a second

15   application node and a second gateway node. The first
application node transmits a data packet as a broadcast
signal to the first gateway node of the first subnetwork.
The first gateway node transmits the data packet as a
point-to-point signal from the first gateway node to the

20   second gateway node of the second subnetwork. The second
gateway node transmits the data packet as a broadcast
signal from the second gateway node of the second
subnetwork to the second application node of the second
subnetwork.

Brief Description of the Drawings

The foregoing and other advantages of the invention will become more readily apparent from the following description of a preferred embodiment of the invention as taken in conjunction with the accompanying drawings, which are a part hereof, in which:

Fig. 1 is schematic view of a system in accordance with the present invention;

Fig. 2 is a schematic view of the system of Fig. 1 under a different condition;

Figs. 3A and 3B are a flow diagram illustrating the operation of the system of Fig. 1;

Fig. 4 is a detailed flow diagram illustrating the operation of a system in accordance with another aspect of the present invention; and

Fig. 5 is a schematic view of a simulation conducted by the system of Fig. 1.

Description of the Preferred Embodiments

In accordance with the present invention, a networked communication system 10 allows simulation of various processes such as a war game with game participants and/or equipment at remote locations or a manufacturing system for various manufacturing processes. Such simulations could utilize existing communication networks within the framework of client server database

systems, instant notification/messaging applications, rudimentary data transfer, etc.

As viewed in Fig, 1, the system 10 may comprise a first device 11, a second device 22, and a third device 33. The first device 11 transmits a data packet as a broadcast signal 107 (i.e., simultaneous sending of the data packet to all nodes) from a first application node 105 of a first subnetwork 101 to a second application node 105 of the first subnetwork and to a first gateway node 103 of the first subnetwork. The first device 11 is typically one or more computers that is/are part of a local area network (LAN) located at a first location. The first gateway node 103 may be a communication hub or a computer that is also part of the LAN at the first location.

The second device 22 transmits the data packet as a point-to-point signal 108 from the first gateway node 103 to one or more remote gateway nodes 104 of other remote subnetworks 102. The second device 22 may be the Internet or some other communication network that is not solely dedicated to this simulation. The remote gateway nodes 104 may be communication hubs or computers that are part of other remote LAN's at remote geographic locations.

The third devices 33 transmit the data packet as a broadcast signal 109 from the remote gateway nodes 104 of the remote subnetworks 102 to at least one application node 106 of each remote subnetwork. The third devices 33 are typically one or more computers that are part of the remote LAN's located at the remote locations other than the first location.

As viewed in Fig. 2, the third devices 33 may transmit other data packets as broadcast signals 111 from the application nodes 106 of the remote subnetworks 102 to the application nodes 106 and the remote gateway nodes 104 of the remote subnetworks. The second device 22 transmits these other data packets as point-to-point signals 112 from the remote gateway nodes 104 to the first gateway node 103 of the first subnetwork 101. The first device 11 transmits the data packets as broadcast signals 113 from the first gateway node 103 of the first subnetwork 101 to the application nodes 105 of the first subnetwork.

The system 10 may utilize a User Datagram Protocol (UDP)/Internet Protocol (IP). This UDP/IP is a connectionless protocol that runs "on top of" IP networks. UDP/IP provides very few error recovery services, offering instead a direct way to send and receive data packets over an IP network. UDP/IP is used

primarily for transmitting data over a network such as the second device 22 (i.e., the internet).

In an UDP/IP network environment, broadcast data packets are bounded to the subnetwork in which they originated. However, point-to-point data packets are not bounded to their subnetwork, but are bounded by the intranet/Internet/firewall for which their destination IP address resides. In other words, if you can successfully locate, or ping, a destination IP address, then the data packet will reach its destination. Distributed Interactive Simulation (DIS) is a protocol for simulation systems on different platforms. DIS enables these platforms to communicate in a common synthetic, or virtual, environment. DIS operates "on top of" the UDP/IP.

DIS requires each platform to be a node in the same subnetwork. By all platforms existing on the same subnetwork, the DIS protocol may transmit data packets, or Protocol Data Units (PDUs), as broadcast signals thereby enabling all PDU's to reach all other platforms, or nodes. The nodes may be part of a local Ethernet subnetwork or a long distance network using dedicated telephone lines (such as via Breeze Box or T1 links) all connected to the same subnetwork.

If multiple subnetworks were connected by direct, or point-to-point, gateway connections in accordance with the present invention, then DIS would not suffice to transmit, or broadcast, data packets via gateways.

5 However, a gateway broadcast conversion process would allow the PDUs to be sent as point-to-point data packets to other subnetworks.

A network simulation system in accordance with the present invention may include such a composite broadcast

10 communication network. The network would include at least two subnetworks. Each subnetwork has one gateway node and one or more application nodes. The gateway nodes communicate to all other gateway nodes by transmitting point-to-point (p2p) PDU's to other gateway

15 nodes at remote subnetworks via an undedicated communication environment such as the internet, as described above.

The gateway nodes implement a gateway topology in that every gateway node transmits and receives from all

20 other gateway nodes. The distributed application nodes communicate to other local application nodes on their local subnetwork by broadcasting PDU's within each local subnetwork. PDU's are broadcasted using the UDP/IP subnetwork protocol layer, described above. As defined

25 by the UDP/IP, broadcasted data packets are bounded to

their local subnetwork. The p2p PDU's, which are not
bounded to their local subnetwork, may be transmitted to
the remote subnetworks by using a direct IP address. To
achieve the comprehensive composite transmission of PDU's

5   on the composite network, the gateway nodes that receive
locally broadcasted PDU's, in turn forward these received
PDU's as p2p transmissions to all other remote gateway
nodes that in turn re-broadcast these PDU's across their
local subnetworks.

10   Each gateway node implements a two-step process in
order to achieve the composite broadcast communication
network in accordance with the present invention. Figs.
1 & 2 illustrate the two steps of the composite broadcast
network. One local subnetwork 101 and three remote

15   subnetworks 102 are interconnected. A local gateway
node 103 is part of the first local subnetwork 101.
Three other remote gateway nodes 104 are part of second,
third and fourth remote subnetworks 102. For this
schematic illustration, there are two local application

20   nodes 105 on the first subnetwork 101, two remote
application nodes 106 on the second subnetwork 102, three
remote application nodes 106 on the third subnetwork 102,
and four remote application nodes 106 on the fourth
subnetwork 102.

Fig. 1 illustrates the application node 105 transmitting a PDU to all other remote application nodes 106. Fig. 2 illustrates the application node 105 receiving a PDU from each remote application node 106 of the second, third, and fourth remote subnetworks 102. In practice, all nodes implement the same algorithm, but have different IP addresses as part of their routing program.

Fig. 1 shows the application node 105 transmitting a PDU as a broadcast signal 107 across the first subnetwork 101. The gateway node 103 listens for locally broadcasted PDU's, such as 107, on its local subnetwork 101. When the gateway node 103 receives the PDU 107, the gateway node converts and forwards the PDU as a p2p signal 108 to the remote gateway nodes 104 in the composite broadcasted network. The remote gateway nodes 104 receive the p2p PDU 108 from the gateway nodes 103, 104. In Fig. 1, all of the remote gateway nodes 104 receive the PDU 108 from the gateway node 103. Any combination of gateway nodes may receive the PDU 108, however, depending upon the address designations. The PDU 108 is then converted for rebroadcasted (illustrated by 109) by the remote gateway nodes 104 across the remote subnetworks 102. The remote application nodes 106

thereby receive the remotely broadcasted PDU's 107 from the application node 105.

Fig. 2 shows application nodes 106 on remote subnetworks 102, each broadcasting one PDU 111. Note that application nodes 106 may simultaneously be receiving locally broadcasted messages from their associated subnetworks 102. The remote gateway nodes 104 listen to the subnetwork broadcasts for locally broadcasted PDU's 111 from their local subnetworks 102. As the remote gateway nodes 104 receive the PDU's 111, the gateway nodes convert and forward the PDU's as p2p PDU's 112 to all other addressed gateway nodes 103, 104 (only PDU's to the local gateway node 103 shown). The local gateway node 103 listens for p2p PDU's 112 from all other gateway nodes 104. The local gateway node 103 receives the PDU's 112 from the remote gateway nodes 104. The p2p PDU's 112 are then converted for rebroadcasted by the local gateway node 103 across the local subnetwork 101 to the local application nodes 105. The composite result is that the local application nodes 105 have received the remotely broadcasted PDU's 111 from the remote application nodes 106 of the remote subnetworks 102. In this way, complete communication is achieved between all parts of all subnetworks 101, 102 in the system 10.

As viewed in Figs. 3A and 3B, the gateway
nodes 101, 102 are invoked with command line
parameters. Internet Protocol (IP) addresses (IP1,
IP2...Ipn) 201 are stored (at 202) and accessed from a

5   Routing Table 203 at each subnetwork. The IP addresses
represent other gateway nodes on remote internet/LAN
subnetworks. The IP address for the local gateway
node 103 on the local subnetwork 101 is IP0. Other
command line parameters may be a broadcast port number, a

10   broadcast IP address, and a unicast port number, all of
which are given default values read from an initial
system configuration. Printing parameters may include IP
addresses and names, DIS 2.0.4 PDU header data, and raw
packet data in hexadecimal format.

15   Each two-step process utilizes the internal Routing
Table 203 that contains the IP addresses of all the other
nodes 103, 104, 105, 106 in the virtual network. The
Routing Table 203 contains all the IP addresses for all
the other nodes except for its own. A local broadcast IP

20   address is also stored in the Routing Table 203.
Typically, the other IP addresses are predetermined at
startup.

          After the Routing Table 203 is configured, a Main
Loop 204 starts a system cycle by determining at 205 if a

25   broadcast PDU 206 from a local application node 105 has

been received and is waiting at a broadcast port 207. If
a broadcast PDU 206 has been received, then the broadcast
PDU is converted to a p2p PDU (at 209) and forwarded as
p2p PDU 210 to all addressed remote gateway nodes 104.

5 Broadcast PDU 206 is converted to a p2p PDU 209 PDU by
simply replacing a broadcast IP address with a p2p IP
address from the Routing Table 203. This conversion may
be accomplished for every IP address in the Routing
Table 203.

10   The cycle is now half complete. The main loop 204
then determines if one or more p2p PDU's 212 from remote
gateway nodes 104 have been received and are waiting at a
p2p port 211. If p2p PDU's 212 have been received, then
the p2p PDU's 212 are converted to broadcast PDU's 213

15 (at 211) and forwarded as a broadcast PDU 214 to the
local application nodes 105. If a p2p PDU has not been
received, the cycle restarts at 217.

      If the p2p PDU 212 is not in the Routing Table 203,
then its IP address is dynamically added to the Routing

20 Table. By dynamically adding the IP address, additional
applications may automatically join the composite
broadcast network with no interruptions or
reconfigurations.

      As illustrated schematically in Figs. 3A and 3B, a

25 computer program product in accordance with the present

invention may perform the above described network

simulation. At step 201, the gateway nodes are defined.

Following step 201, step 202 stores the addresses for

each of the gateway nodes in a routing table. Following

step 202, step 204 accesses a main loop for network

simulation. Following step 204, step 205 determines

whether a data packet has been received from a subnetwork

broadcast port. If the determination of step 205 is YES,

then step 209 sends the data packet to a gateway port.

Following step 209, step 210 sends the data packet across

an undedicated network to other subnetworks as point-to-

point signals.

Step 211 determines whether another data packet has

been received from a gateway port for the other

subnetworks. If the determination of step 211 is YES,

then step 213 sends the other data packet to a broadcast

port. Following step 213, step 214 sends the other data

packet across the subnetwork as a broadcast signal.

Also, if the determination of step 211 is YES, then

step 215 determines whether the IP address of the data

packet is already stored in the routing table. If the

determination to step 215 is NO, then step 216 adds the

IP address to the routing table.

In accordance with another aspect of the present

invention, as viewed in Figure 4, UDP/IP addresses 307,

308, 311, 312 are used to achieve the total composite

broadcast communication between application nodes 303,

304 (similar to nodes 105, 106 in Figs. 1 & 2). The

gateway nodes 301, 302 (similar to nodes 103, 104 in

5   Figs. 1 & 2) use dedicated port numbers to send and

receive broadcast PDU's 311, 312 and p2p PDU's 307, 308,

309. Each gateway node 301, 302 and application

node 303, 304 is bounded to its respective port to

lockout the subsequent allocation of those ports to

10   another node. Typically, each broadcast PDU 311, 312 is

an Ethernet Protocol Data Unit (EPDU) having a 16 bit

port number and a 48 bit IP address that is used by the

UDP/IP Protocol for the correct routing of PDU's. The

p2p data streams 307, 308, 309 link the subnetworks 305,

15   306 as one network.

As viewed in Fig. 5, a synthetic military

environment software packet (ModSAF - Modular Semi-

Automated Forces) 408 may be used as a common database

platform. An undedicated intranet 407, instead of the

20   Internet, may link two LAN Ethernet subnetworks 405, 406,

one each at a site. Six simulated entities, such as four

Surface to Air Missiles (SAM's) and two Trucks (T's) may

simulate targets at one site 12 (i.e., New York). Two

real-time man-in-the-loop observer simulators, a

25   helicopter, and a jet airplane may also be simulated at

the site 12. Four real-time simulated entities, such as

Unmanned Air Vehicles (UAVs), may be simulated at another

site 14 (i.e., Texas). The UAV simulators at site 14 may

have embedded software algorithms that autonomously

5   search and destroy SAM's (at site 12). The combination

of real-time man-in-the-loop observer simulators and SAM

simulated sites engaging in a real-time test from remote

sites 12, 14 via a composite broadcast network 10 may be

conducted in this way. This system 10 provides the

10   advantage of sharing remote hardware across a multitude

of facilities/locations within a network system.

In accordance with another feature of the present

invention, a method allows communication within a network

(Figs. 1 & 2). The method includes the steps of:

15   transmitting a data packet as a broadcast signal 107 from

a first application node 105 of a first subnetwork 101 to

a second application node 105 of the first subnetwork and

to a first gateway node 103 of the first subnetwork;

transmitting the data packet as a point-to-point

20   signal 108 from the first gateway node 103 to a second

gateway node 104 of a second subnetwork 102; and

transmitting the data packet a broadcast signal 109 from

the second gateway node 104 of the second subnetwork 102

to at least one application node 106 of the second

25   subnetwork.

The method may further includes the steps of: transmitting another data packet as a broadcast signal 111 from the at least one application node 106 of the second subnetwork 102 to the second gateway node 104

5   of the second subnetwork;   transmitting the other data packet as a point-to-point signal 112 from the second gateway node 104 to the first gateway node 103 of the first subnetwork 101; and transmitting the data packet as a broadcast signal 113 from the first gateway node 103 of

10   the first subnetwork to the first application node 105 of the first subnetwork 101.

       In accordance with still another feature of the present invention, an apparatus 400 may simulate a war game (Fig. 5) with game participants and equipment at

15   remote locations 12, 14 from each other.   The apparatus 400 includes a first means 401, 403, a second means 407, and a third means 402, 404.   The first means 401, 403 transmits a data packet as a broadcast signal from a first application node 403 of a first

20   subnetwork 405 to a second application node 403 of the first subnetwork and to a first gateway node 401 of the first subnetwork.   The second means 407 transmits the data packet as a point-to-point signal from the first gateway node 401 to a second gateway node 402 of a second

25   subnetwork 406.   The third means 402, 404 transmits the

data packet as a broadcast signal from the second gateway node 402 of the second subnetwork 406 to at least one application node 404 of the second subnetwork.

The third means 402, 404 may transmit another data packet as a broadcast signal from the at least one application node 404 of the second subnetwork 406 to the second gateway node of the second subnetwork. The second means 407 may transmit the other data packet as a point-to-point signal from the second gateway node 402 to the first gateway node 401 of the first subnetwork 405. The third means 402, 404 may transmit the other data packet as a broadcast signal from the first gateway node 401 of the first subnetwork 405 to the first application node 403 of the first subnetwork 405.

The first means 401, 403 may comprise a subnetwork consisting of linked computers. The second means 407 may comprise portions of the Internet or another undedicated system. The third means 402, 404 may comprise a local subnetwork consisting of linked computers.

Although the invention has been described in conjunction with the preferred embodiments, it is to be appreciated that various modifications may be made without departing from the spirit and scope of the invention as defined by the appended claims.